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(56) Documents cited
GB 2222266 A EP 0443137 A EP 0118075 A
US 5085525 A US 4963036 A US 4652133 A

(58) Field of search
UK CL (Edition L) H4D DLAT DLAX DLPC DLRA
INT CL^5 G01B
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(54) **Object examination**

(57) The invention relates to a scanning device 2 comprising an enclosure in which at least a camera 4 including camera optics 8, a laser 3 including laser optics 7 and which produces a stripe of laser light, and a data processor 5 are enclosed. The scanning device comprises one or more viewing means provided either by one or more cameras or a single camera in combination with mirrors 6. The data processor can be programmed to analyse the scanning data and provide output instructions to various peripheral devices and machine and process control systems directly.

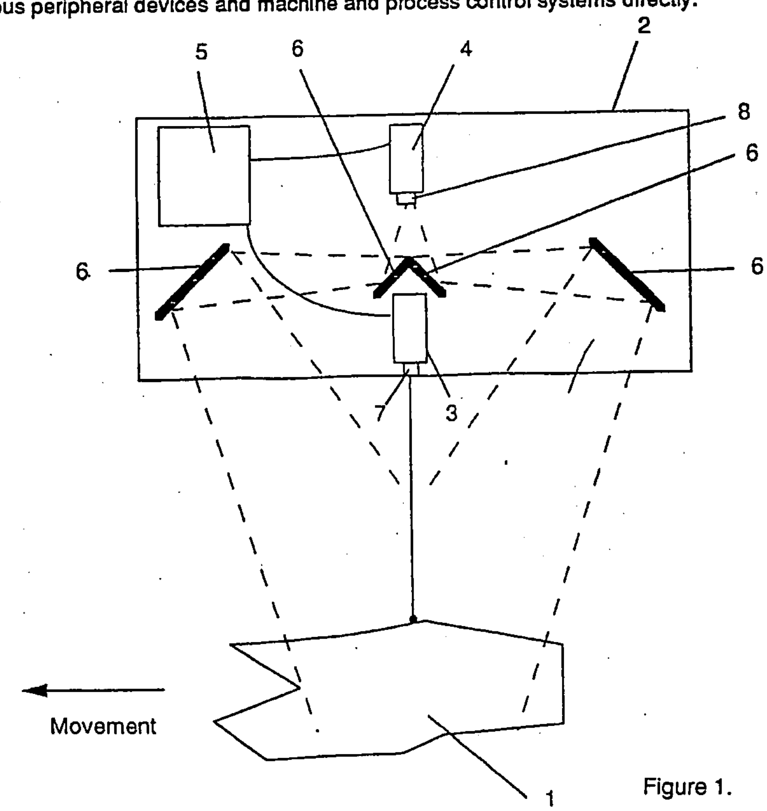

Figure 1.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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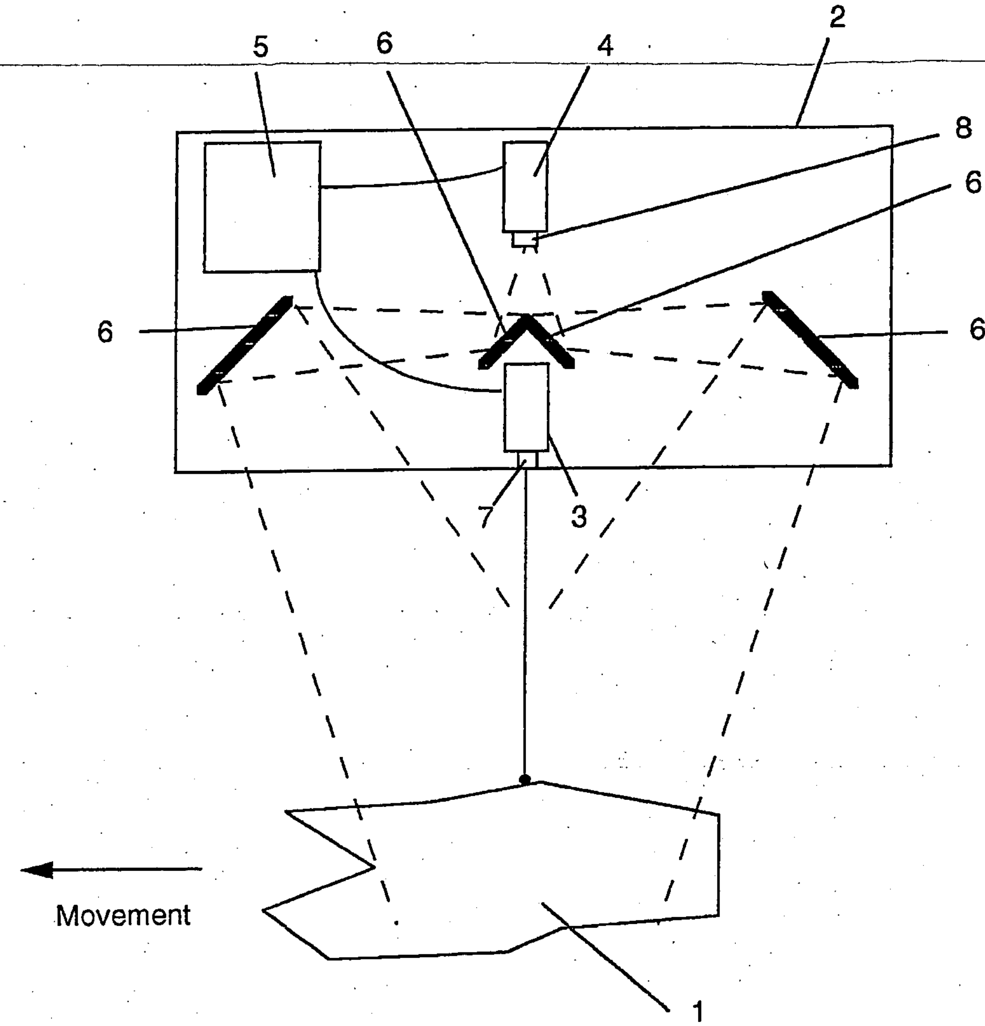

Figure 1.

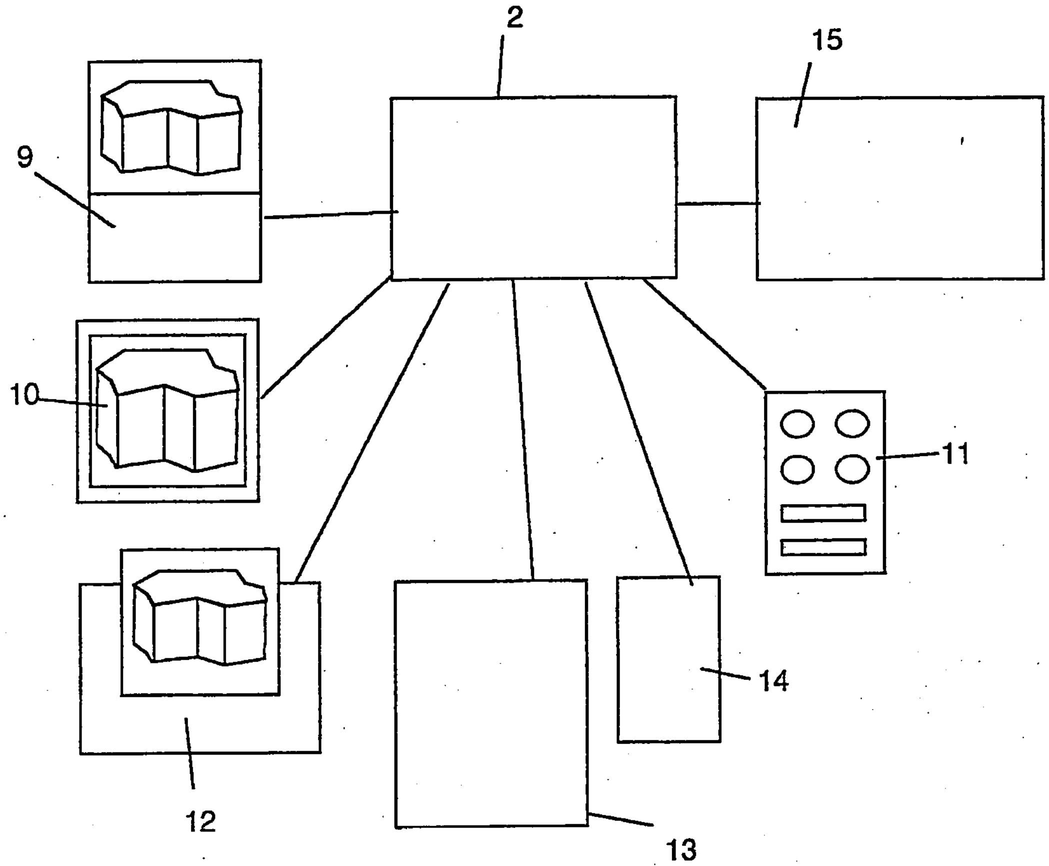

Figure 2.

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SCANNING UNIT

This invention relates to an integrated device for the three dimensional surface scanning and analysis of an object or scene in real-time with the capability to provide feedback to a process controller or to control a process directly.

There are numerous applications which require the real-time monitoring of the surface of an object or scene. The main uses are for quality assurance and process control; there are also applications in reverse engineering, object recognition and vehicle guidance. Examples of the main uses are: the inspection of discrete products with the provision of pass/fail and trend information, the scanning of sides of bacon in the food industry with information fed to the bacon slicing machine to control the thickness of slices according to fixed weight requirements and the control of an extrusion or rolling process in the plastics and steel industries with information fed back in real time to the process control system.

There are numerous methods of capturing the shape of an object, including a mechanical or optical or electromagnetic single point probe, holographic systems, Moiré fringe systems, ultrasound systems, fast Fourier transform systems, photogrammetric systems, time of flight systems and triangulation techniques using structured light. Each method has different advantages and disadvantages in different classes of application.

It is an object of this invention to provide a new three dimensional surface scanning unit with the capability to process the scanned information and may also communicate with the process being scanned, that is a self-contained unit and does not require any associated computing equipment in normal operation.

According to the invention, there is provided an enclosed unit which consists of a method of capturing the surface shape of an object and a method of analysing the object. The enclosed unit is self-contained, but may be directly connected to the process in order to control it, or be connected to a device that controls a process such as a Programmable Logical Controller.

It is also an object of this invention, that the functioning of the unit be specified for the application for which it is installed by temporarily connecting a programming processor to the unit. The programming processor would usually be a small, portable computer. The connection of a programming processor for specifying the functioning of an unit is commonly used on programmable controllers and on motion control systems. The connection of a programming processor to a scanning unit for specifying its functioning which may be removed for operation is novel and provides a lower cost system which occupies less space than if a separate programming processor were required for its operation.

A display device may be connected to the unit to provide information on the functioning of the unit and the results of its operation. A control panel may be connected to the device for the operator to control the functioning of the unit.

The use of a CCD matrix rather than an area position sensing device or a linear position sensing device with a scanned spot/viewing point enables the processing unit to apply algorithms based on the knowledge of the light levels at each point in the matrix. These algorithms can determine not only the position but can identify well-known situations when errors in position are likely and to either output error signals or to compute accurate positions taking into account the full data. Position sensing devices do this process in hardware with the disadvantage that false positions may be generated due to optical effects such as those found at the edge of an object when part of the projected light is lost or from flare and reflections at a shoulder. The position sensing device cannot output error signals or provide the raw data that a CCD matrix can for calculating a more accurate position.

It is also an object of this invention, to have the facility to control the power of the lasers, the exposure time of the CCD matrix array and the gain of the CCD for each measurement. With this method, if some parts of the laser stripe are not visible with a standard exposure at low laser power, then a second exposure (at the same physical position relative to the object) which is either longer or with more laser power can be made to render these points visible.

The laser sources may be broadband or narrowband. The use of a broadband laser source can overcome some optical characteristics generated by the surface texture. An example is the generation of speckle patterns by the interaction of a narrowband source with a machined surface. The speckles thus produced distort the stripe such that any measurements made are significantly less accurate than without the speckle effect.

A specific embodiment of the invention will now be described with reference to Figure 1 which is an outline of system layout.

A scanning device [2] comprising an enclosure in which at least a camera [4] including lens [8], a laser [3], comprising laser optics [7], and which produces a stripe of laser light, and a data processor [5] are enclosed.

The object or scene being scanned [1], moves relative to the scanning unit [2]. The scanning unit is a rigid enclosure to which the components [3,4,5,6,7 and 8] are firmly attached such that there is no scope for movement of the components [3,4,5,6,7 and 8] relative to each other in normal operation. The scanning unit operates on the principal of structured light triangulation. The source of structured light is usually at least one laser [3] which may have optics [7]. The source could be a slit of light or any other source that projects a

relatively thin stripe of light onto the object or scene [1]. The light stripe(s) is viewed at an angle by at least one camera [4]. The camera(s) and laser(s) are connected to a data processor [5] comprising at least one electronic processing board. The camera(s) may not view the object directly and instead their optical paths may include reflection by means of a system of mirrors [6].

The scanning unit can accommodate at least one stripe triangulation. Several triangulations may be carried out by at least one stripe and at least one viewpoint. One camera may, by the use of mirrors simultaneously look from at least two viewpoints; the combination of components to view from a viewpoint is called a viewing means. Similarly a single laser may be used to project two stripes by means of a system of mirrors and a beam splitter. The advantage of having at least two triangulations is that shadowing or eclipsing caused by the geometry of the object obstructing the paths of the light to the surface and from the stripe to the camera's viewpoint can be overcome by having at least two viewpoints and/or at least two stripes.

Although the scanning unit is self-contained, the positioning of the camera(s), laser(s) and mirror(s) relative to each other may be adjusted to accommodate different fields of view of the object or scene and different positioning of the scanning unit relative to the object or scene. This adjustment is also essential to optically align the system at the time of installation.

Laser optics [7] may be used in conjunction with the laser to produce stripes of different thicknesses. One method is to use a rod lens, which spreads a beam of light into a stripe of light. The rod lens may be used in conjunction with focusing optics to focus the thickness of the stripe at a certain distance from the optics. A second method is the use of a scanning element such as a polygon mirror or galvanometer mirror to scan a spot to produce a stripe.

Camera optics [8] may be used to change the field of view. The preferred method is a lens of fixed focal length. Variable focal length lenses (zoom lenses) may be used and anamorphic optics in which the focal length in orthogonal directions is variable may also be used.

A number of possible combinations of camera(s), laser(s) and mirror(s) may be used and this document covers any possible combination of these elements within an enclosed scanning unit. In addition, at least two scanning units may simultaneously scan the same object or scene from different positions and these scanning units may be connected to each other so that signals are passed from one to another.

In Figure 2 the connection of the scanning unit to a variety of other devices is shown. The unit may be connected to a

programming processor [9], a display device [10], a control panel [11], a printer [12], the process in the form of other sensors and actuators ~~[13], a process control system [14] and~~ another scanning unit [15]. This list provides common examples of probable interconnections and does not exclude connection to other types of device. The interconnections of devices may all be direct to the scanning unit or the devices may be connected by means of a network.

In further embodiments of this invention other principles of scanning may be incorporated including those given in the list of methods above.

CLAIMS

1. A scanning device [2] comprising an enclosure in which at least a camera [4] including lens [8], a laser [3], comprising laser optics [7], and which produces a stripe of laser light, and a data processor [5] are enclosed.

2. A scanning device according to claim 1, characterised in that the scanning device comprises at least two viewing means.

3. A scanning device according to claim 2, characterised in that the viewing means are provided by at least two cameras.

4. A scanning device according to claim 2, characterised in that viewing means are provided by a combination of at least one camera and at least one mirror.

5. A scanning device according to claim 1, characterised in that the laser [3] with laser optics [7] projects at least two laser stripes.

6. A scanning device according to claim 5, characterised in that the laser stripes are in parallel planes.

7. A scanning device according to claim 5, characterised in that the laser stripes are co-planar.

8. A scanning device according to claim 5, characterised in that the laser stripes are in coincident planes.

9. A scanning device according to claim 5, characterised in that the laser stripes are divergent.

10. A scanning device according to claims 1 to 9, characterised in that the data processor [5] can be programmed by the addition of a programming processor [9].

11. A scanning device according to claims 1 to 10, characterised in that it comprises connecting means to a display device [10].

12. A scanning device according to claims 1 to 11, characterised in that it comprises connecting means to a control panel [11].

13. A scanning device according to claims 1 to 12, characterised in that it comprises connecting means to a printer [12].

14. A scanning device according to claims 1 to 13, characterised in that it comprises connecting means to a machine or process [13].

15. A scanning device according to claims 1 to 14, characterised in that it comprises connecting means to a machine or process control system [14].

16. A scanning device according to claims 1 to 15, characterised in that it comprises connecting means to other scanning devices [15].

17. A scanning device according to claims 1 to 16, characterised in that the laser optics [7] can be adjusted to focus the stripes at different distances from the scanning device.

18. A scanning device according to claims 1 to 17, characterised in that the camera [4] comprises camera optics [8] which can be adjusted to scan objects [1] at different distances from the scanning device.

19. A scanning device according to claims 1 to18, characterised in that the camera optics [8] comprise anamorphic optics.

20. A scanning device according to claims 1 to 19, characterised in that the camera [4], laser [3] and mirror [6] and fixed in position with respect to each other by a rigid enclosure such that they cannot move relative to each other in normal operation.

21. A scanning device according to claims 1 to 20, characterised in that the laser optics [7] form a stripe using fixed optical elements.

22. A scanning device according to claims 1 to 21, characterised in that the laser optics [7] include a rotating element for scanning a spot to achieve a stripe.

23. A scanning device according to claims 1 to 22, characterised in that the laser optics [7] include a device for optically generating at least two stripes [10] from a single laser [3].

24. A scanning device according to claims 1 to 23, characterised in that algorithms or heuristic rules are used in the data processor to identify optical effects which lead to error in the standard position calculation caused by said optical effects during scanning.

25. A scanning device according to claim 24, characterised in that algorithms or heuristic rules based on knowledge of the optical effects that lead to error in the standard position calculation are used in the data processor to calculate an accurate position.

26. A scanning device according to claims 1 to 25, characterised in that the laser [3] may be broadband or narrowband.

27. A method of scanning an object or scene [3] comprising the following steps:

a) scanning the object or objects
b) analysing the scanning data
c) outputting the results of the analysis

28. A method of scanning an object or scene [3] comprising the following steps:

a) scanning the object or objects
b) analysing the scanning data
c) carrying out preprogrammed actions on a machine or process depending on the results of the analysis.

29. A scanning method according to claims 27 to 28 characterised in that at least two exposures are made at the same or close to the same physical position, one at a different light level to the other.

Patents Act 1977
E: miner's report to the Comptroller under Section 17 (The Search Report)

Application number

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Relevant Technical fields

(i) UK Cl (Edition L) H4D (DLAX DLAT DLPC DLRA)

(ii) Int Cl (Edition 5) G01B

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

Search Examiner

DR E P PLUMMER

Date of Search

5 FEBRUARY 1993

Documents considered relevant following a search in respect of claims 1

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2222266 A	(CANON) whole document	1 at least
X	EP 0443137 A	(NORDISCHER MASCHINEBAU) whole document	1 at least
X	EP 0118075 A	(GENERAL ELECTRIC) whole document	1 at least
X	US 5085525	(SQUARE D) whole document	1 at least
X	US 4963036	(WESTINGHOUSE) whole document	1 at least
X	US 4652133	(WESTINGHOUSE) whole document	1 at least

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

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